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AGITATING BALL MILL WITH RADIAL AGITATOR

The invention relates to an agitating ball mill according to the preamble of claim 1.

Such agitating ball mills have a grinding chamber containing grinding media, a stator and a rotor, which are arranged in the grinding chamber, an input opening and an output opening for feeding and removing grinding material to or from the grinding chamber, as well as a grinding medium separation device arranged in the grinding chamber upstream from the output opening, which is used to separate grinding media entrained in the grinding material from the grinding material before the latter is removed from the grinding space through the output opening.

Agitating ball mills are used in the area of foodstuffs and in the manufacture of fine particles down to the nanometer range in size. Particles or agglomerates suspended in a liquid are here conveyed into the grinding chamber, and comminuted or dispersed in the grinding chamber by means of auxiliary grinding media before being conveyed out of the grinding chamber. To prevent the auxiliary grinding media from becoming dragged out of the agitating ball mill by the liquid stream of grinding material during this wet grinding process, resulting in the loss of the agitating ball mill and contamination of the grinding material, the auxiliary grinding media are held back in the grinding chamber by a separation device. A separating gap, grading screen or cellular wheel are used as separation devices. Essentially spherical elements made out of steel, glass, ceramic or plastic are used as the auxiliary grinding media.

In order to increase the mechanical grinding power introduced into the grinding material in the grinding chamber, the rotor and/or stator of known agitating ball mills is provided with pins that extend into the grinding chamber. As a result, impacts between the grinding material and the pins during operation directly contribute to the grinding power on the one hand. On the other hand, an indirect contribution to grinding power is made by impacts between the pins and the (auxiliary) grinding media entrained in the grinding material and subsequent impacts between the grinding material and grinding media. Finally, the shear and expansion forces acting on the grinding material also help comminute the suspended grinding material particles.

The object of the invention is to achieve an enhanced grinding effect relative to known agitating ball mils at a prescribed rotor/stator geometry or grinding chamber geometry and at a prescribed rotor speed.

This object is achieved with the agitating ball mill according to claim 1.

The fact that the rotor is essentially shaped like a rotationally symmetric element and the stator is formed by an essentially complementary inner surface of the grinding chamber enables a high power density for the mechanical introduction of energy into the grinding material as well as the greatest possible ratio between the processing area space and processing area volume, and hence an optimal cooling of the grinding material during wet grinding or comminuting.

The fact that the rotor and stator have pins distributed over their entire respective surface, extending from the respective surface and projecting

into the processing space enables the direct and indirect action of the pins distributed over the entire grinding chamber volume, i.e., the impacts between the grinding material and pins, the impacts between the pins and the grinding media entrained in the grinding material, as well as the shearing and expansion forces triggered by the pins in the suspension consisting of grinding material and grinding media, which together help comminute the suspended grinding material particles.

As a whole, then, improved grinding power is achieved, accompanied simultaneously by an evening out of grinding intensity, and hence also of an unnecessary strain on the grinding material, e.g., as the result of local overheating, in the entire grinding chamber.

It is particularly advantageous for the grinding material input opening to be arranged in a radially outer area of the grinding chamber, and the grinding material output opening to be arranged in a radially inner area of the grinding chamber. During operation, an equilibrium essentially sets in at on the auxiliary grinding media between a radially outwardly directed centrifugal force component due to the rotation of the rotor around its rotational axis and a radially inwardly directed drag force component due to the grinding material flowing radially from the outside in. The flow of grinding material is maintained by a separate pump, for example. This exposure to centrifugal force provides a "dynamic" relief for the separation device situated radially inside the grinding material output opening, i.e., most of the auxiliary grinding media is suspended, more or less stationary, in the radially outer areas of the processing area, and forms a "swarm" of auxiliary grinding media through which the grinding material is pumped. The few

auxiliary grinding media that get into the radially inner area of the processing area in the process are then caught by the separation device. As a result, the separation device is protected and subjected to less wear.

The rotor can essentially be shaped like a truncated cone, wherein the grinding material input opening is arranged in the area of the wide truncated cone end, and the grinding material output opening is arranged in the area of the narrow truncated cone end of the grinding chamber. As an alternative, the rotor can also essentially be shaped like a double truncated cone. In both cases, the grinding material is preferably pumped radially from the outside radially inward.

As a further alternative, the rotor can essentially be shaped like a cylinder, wherein the grinding material input opening is arranged in the area of the first cylinder end, and the grinding material output opening is arranged in the area of the second cylinder end of the grinding chamber, and the grinding material is essentially spirally transported along the cylinder jacket of the rotor through the processing area.

In another advantageous embodiment, the rotor is essentially shaped like a disk, wherein the grinding material input opening is arranged in the radially outer peripheral area, and the grinding material output opening is arranged in the radially inner axial area of the grinding chamber, so that the grinding material again flows through the processing area from the outside in. Here as well, the aforementioned equilibrium between a centrifugal force component and drag force component is also established at the auxiliary grinding media during operation. The grinding material pumped from outside in then once again

provides the "dynamic" relief for the radially inner separation device.

It is particularly advantageous for the disk-shaped rotor to have pins on both its two flat disk surfaces and not its peripheral surface. The radially most outwardly lying pins are the fastest of all pins during operation. Since most of the auxiliary grinding media are radially suspended outside, a significant portion of the grinding effect is exerted in just this peripheral area of the processing area alone, resulting in a clearly increase in grinding power at the disk edge by comparison to an agitating ball mill without pins.

The grinding chamber with its stator and rotor and the separation device can preferably be pivoted into a swiveled position in such a way that the separation device arrives at a high location, which is preferably higher than most of the entire grinding chamber volume. This makes it possible to remove the separation device without evacuating the auxiliary grinding medium or product, since the auxiliary grinding medium swell does not reach the height of the separation device in the swiveled position. In addition, this allows the use in the agitating ball mill of a rotatable separation device with spoke or leaf-like elements, e.g., a spoke wheel, paddle wheel or cellular wheel, wherein the separating effect of the separation device only comes about when it starts to rotate. Because the processing zone can swivel according to the invention, the separation device can be made operational in this case, as long as the processing zone is tilted, and the separation device is situated at the high location. After activation, the processing zone is then tilted to the operational setting, in which the auxiliary

grinding media now arrive at the separation device, which now exerts a separating action.

Once between 50 % and 100 % of the entire grinding chamber volume lies under the separation device in the swiveled position, depending on the grinding medium quantity in the agitating ball mill, no auxiliary grinding media will be able to fall out of the grinding chamber owing to the use of a "rotatable" separation device that is inactive when idle, or the lack of a dismantled separation device.

The swiveled, high location of the separation device is best the highest location of the agitating ball mill achievable via swiveling. This facilitates access to the separation device. In addition, auxiliary grinding media located in or on the separation device can be poured out or stripped into the grinding chamber without any problem via the opening to the grinding chamber during the dismantling of the separation device.

The swiveling position is best a non-operating position of the agitating ball mill. In the operating position of the agitating ball mill, the rotational axis of the rotor is essentially arranged horizontally.

The separation device is preferably exchangeable. For example, it can be a self-cleaning grading screen or a paddle wheel.

In another advantageous embodiment, the rotor is a hollow rotor with holes arranged radially inside the rotor, and holes arranged radially outside the rotor. During operation, the auxiliary grinding media are here transported along with a portion of the grinding material flow inside the rotor from a radially inner

hole to one of the radially outer holes via the centrifugal action of the rotor, and transported outside the rotor with the entire grinding material flow from the radially outer hole to the radially inner hole via the pumping action of the grinding material input opening, so that the auxiliary grinding media circulate inside the agitating ball mill.

The radially inner hole preferably extends in the circumferential direction given an inner radius Ri at the rotor, and the radially outer hole preferably extends in the circumferential direction given an outer radius Ra at the rotor. This facilitates the entry of auxiliary grinding media along with a portion of the grinding material flow into the rotor cavity, as well as the exit of auxiliary grinding media along with this portion of grinding material flow out of the rotor cavity.

In a particularly preferred embodiment, the hollow rotor exhibits inner channels, which each form a fluid connection between a radially inner hole and a radially outer hole. These spoke-like channels arranged inside the rotor exert a strong centrifugal force on the auxiliary grinding media, so that the latter are transported back out efficiently.

Other advantages, features and possible applications of the invention may be gleaned form the description of an exemplary embodiment based on the drawing, which is not to be construed as limiting. Shown on:

Fig. 1 is a perspective view of an agitating ball mill according to the invention in an operating position;

Fig. 2 is a perspective view of the agitating ball mill on Fig. 1 in a tilted, non-operating position or maintenance position;

Fig. 3 is a magnified perspective view similar to that of Fig. 2 of the agitating ball mill according to the invention with dismantled separation device;

Fig. 4 is a perspective view similar to that of Fig. 1 of the agitating ball mill according to the invention;

Fig. 5 is a perspective view of the agitating ball mill on Fig. 4 with open processing zone;

Fig. 6 is a sectional view of half of an agitator of a respective exemplary embodiment of the agitating ball mill according to the invention, wherein the cutting plane is selected in such a way as to encompass the rotational axis A-A of the agitator;

Fig. 7 is a sectional view of a diagrammatically depicted agitator, whose rotor has inner channels and enables grinding medium circulation.

Fig. 1 shows an agitating ball mill according to the invention in its operating position with horizontal rotor rotational axis. The agitating ball mill is secured to a vertical element 2, which is connected with an engine bracket 1. A motor 3 uses a belt transmission 4 to drive a pulley 5, which is secured with the rotor 21 (see Fig. 5) of the agitating ball mill so that it cannot rotate via a shaft situated in a bearing 6 arranged under a cladding 8 (see Fig. 4). The

rotationally driven rotor 21 rotates in the grinding chamber 9. The grinding material to be ground passes through a grinding material input opening 11 arranged radially outside and radially on the grinding chamber 9 and into the grinding chamber 9, and exits the grinding chamber 9 via a grinding material output opening 12 arranged radially inside and axially on the grinding chamber. The grinding chamber essentially consists of three parts, specifically a first, flat grinding chamber wall 13, a curved grinding chamber wall 14 on the grinding chamber periphery, and a second flat grinding chamber wall 15. The curved grinding chamber wall 14 and the second flat grinding chamber wall 15 are rigidly connected with each other to form a single unit. This unit 14, 15 is coupled to the first flat grinding chamber wall 13 by means of a hinge 10. In addition, a cylindrical screen jacket 16 is rigidly connected with the second flat grinding chamber wall 15, and arranged centrally on the grinding chamber wall 15, projecting axially to the outside. Located inside this screen jacket 16 is a separation device 18 in the form of a cylindrical grading screen (see Fig. 3). The grinding material output opening 12 is formed by an axially running pipe, which ends inside the cylindrical grading screen 18. Situated outside the output opening 12 is an inclined, downwardly running groove 17, with which grinding material and grinding media can be discharged from the processing zone in a controlled fashion.

Fig. 2 shows the agitating ball mill according to the invention on Fig. 1 with a vertical rotational axis of the rotor in the tilted position. The reference numbers and elements corresponding thereto are the same as on Fig. 1. As evident, all function elements 3 to 17 of the agitating ball mill on Fig. 2 are tilted by 90° around a horizontal swiveling axis. Only the engine

bracket 1 and vertical element 2 are in the same position as on Fig. 1. In this tilted position, the screen jacket 16 is more readily accessible, so that, during maintenance, the grading screen 18 (see Fig. 3) can be more easily dismantled and installed. In addition, auxiliary grinding media (not shown) adhering to the grading screen or jammed therein can be easily stripped or shaken into the grinding chamber 9.

Fig. 3 shows the tilted agitating ball mill according to the invention as on Fig. 2, but magnified somewhat. The reference numbers and elements corresponding thereto are the same as on Fig. 1 and Fig. 2. In addition, the grading screen 18 is shown in the dismantled state. As best illustrated by Fig. 3, the upper cylinder edge of the cylindrical grading screen 18 has a flange 19 with holes, which is used to secure the grading screen 18 to the screen jacket 16 with screws 20 during reinstallation. The grading screen 18 could not be dismantled and installed in the operating position with horizontal rotational axis of the rotor (see Fig. 1) without any preparatory work. The grinding space content and in particular the grinding media would have to be discharged first.

In addition, the tiltability of the agitating ball mill according to the invention makes it possible to use a separation device other than the "passive" grading screen, e.g., a cellular wheel or a paddle wheel, which can only separate out auxiliary grinding media when operational, i.e., during rotation. If the goal is to stop an agitating ball mill equipped with such an "active" separation device, it can be tilted in the vertical position with a vertical rotational axis beforehand. The reverse process is followed during renewed startup. The rotor and "active" separation device are first made to rotate with a vertical

rotational axis while the agitating ball mill is still tilted, so that the separating action of the "active" separation device is restored, whereupon the agitating ball mill is tilted back into the horizontal operating position with a horizontal rotational axis.

Fig. 4 shows the agitating ball mill according to the invention magnified somewhat by comparison to Fig. 1. The reference numbers and elements corresponding thereto are the same as on Fig. 1, Fig. 2 and Fig. 3. As opposed to Fig. 1, the cladding 8 was here omitted, revealing the bearing 6 for the drive shaft and carrier 7 of the pivoting engine part.

Fig. 5 shows the agitating ball mill on Fig. 4 with opened processing zone, i.e., in a state where the grinding chamber 9 is opened. The grinding chamber 9 was opened by swiveling the unit 14, 15, 16 comprised of the second flat grinding chamber wall 15, the curved grinding chamber wall 14 and the screen jacket 16 and coupled to the first flat grinding chamber wall 13 via the hinge 10 away from the grinding chamber wall 13. Visible here is the disk-shaped rotor 21 screwed to the drive shaft so that it cannot rotate, whose flat surface areas are equipped with pins 22, and whose curved edge areas are equipped with additional pins 23 along the circumferential direction. Corresponding pins opposing the pins 22 and radially shifted relative thereto are also arranged on the stator surfaces, i.e., on the side of the grinding chamber walls 13 and 15 facing into the processing space. The grading screen 18 concentrically arranged inside the screen jacket 16 can be discerned in the middle of the swiveled-away unit 14, 15, 16. One characteristic feature involves the pins 26, which are also arranged on the rotor disk 21, but only on their side facing the grinding chamber wall 15, thereby generating a cleansing turbulence around a

static separation device. These screen cleaning pins, whose length corresponds roughly to the cylinder length of the grading screen, are arranged approximately concentrically around the midpoint of rotor disk 21, and extend parallel to both each other and the rotational axis of the rotor, thereby extending into the gap between the grading screen 18 and screen jacket 16 when closing the grinding chamber, i.e., swiveling back the unit 14, 15, 16. All elements of the grinding chamber wall, i.e., the first flat grinding chamber wall 13, the curved grinding chamber wall 14, and the second flat grinding chamber wall 15, along with the screen jacket 16, have cooling channels (not shown). The rotor disk 21 incorporates holes 27 that unite both processing space halves, and are located in proximity to the connecting points between the screen cleaning pins 26 and rotor disk 21, concentrically around the midpoint of the rotor disk 21.

During operation, the product to be ground (e.g., suspension with particles to be comminuted) is pumped via the input opening 11 into the grinding chamber 9, in which the driven rotor disk 21 rotates. The interaction between the grinding media (not shown) and the pins 22, 23 on the rotor disk 21, as well as the pins 24, 25 on the stator, comminutes the particles suspended in the product. The product comminuted and dispersed in this way as it passes through the processing space from the outside in finally arrives at the gap between the grading screen 18 and screen jacket 16, and passes through the grading screen 18 toward the output opening 12. If, despite the high centrifugal field in the grinding chamber 9 and its higher density relative to the grinding material, several grinding media get as far as the grading screen owing to "unfortunate" impacts and/or entrainment by the grinding material flow, they are retained there at the

latest. The screen cleaning pins 26 circulating relative to the resting grading screen 18 on its surface with the rotor speed ensure that the grinding material is vigorously swirled with velocity components tangential to the surface of the grading screen. This keeps the grading screen largely free of deposits and conglutinations. In addition, strays are prevented from accumulating among the auxiliary grinding media in the grading screen and quickly jamming the grading screen together with the grinding material.

Fig. 6 shows a side view of half an agitator of a respective exemplary embodiment of the agitating ball mill according to the invention, wherein the cutting plane is selected in such a way that the rotational axis A-A of the agitator lies therein. The radially inner area of the agitator near the axis was cut away, since its design is largely independent for the agitator shown on the figure.

The disk-shaped rotor marked 21 overall is interspersed by axially parallel pins 22, which are fitted, screwed or otherwise secured in axially parallel boreholes of the rotor disk 21, and project into the grinding chamber from the rotor disk 21 on either of its sides. In addition, pins 23 extending radially out are spaced apart from each other in a circumferential direction on the outer edge of the rotor disk 21. The stator or grinding space casing is formed by the first flat grinding chamber wall 13, the curved grinding chamber wall 14 as well as the second grinding chamber wall 15 (compare Fig. 5). The two flat grinding chamber walls 13 and 15 have pins 24 and 25 extending into the grinding space, which are offset relative to the pins 22 of the rotor disk 21. The radial pins arranged on the outer edge of the rotor disk 21 contribute significantly to the overall grinding capacity, since

both these pins 23 as well as the grinding material exhibit particularly high speeds in this radially outermost area, so that a great deal of energy is expended there between the pins 23 and the grinding material or the auxiliary grinding media. The mentioned grinding chamber walls 13, 14 and 15 have claddings 28, 29 and 30 on the grinding space side, which consist of a non-abrasive material. Also subjected to a high level of wear, pins 22, 23, 24 and 25 can ideally be replaced. The side of the flat grinding chamber wall 15 facing the rotational axis A-A has the only partially shown screen jacket 16, which covers the grading screen 18 (compare Fig. 5).

Fig. 7 shows a sectional view of a diagrammatically depicted agitator, whose rotor has inner channels, and enables a grinding medium circulation along the sketched-in arrow. To ensure clarity, the pins 22, 23, 24 and 25 according to the invention shown on Fig. 6 and Fig. 6 [sic] were omitted from Fig. 7. The rotor marked 21 overall has at least one radially inner hole 21a at a radial distance Ri from the rotational axis A-a, and at least one radially outer hole 21b at a radial distance Ra from the rotational axis A-A. A flow channel is formed between these holes 21a and 21b via channels 21c inside the rotor 21. The stator is formed by the grinding chamber walls 13, 14 and 15 (compare Fig. 5). During operation, both drag and inertia forces act on the grinding media distributed in the grinding material (shown as black dots). In the grinding space area between the rotor 21 and the grinding chamber walls 13 and 15 forming the start, the grinding media are dragged toward the inside along with the grinding material pumped into the grinding space radially from outside through the grinding material input opening 11 (compare Fig. 1, Fig. 5) via the channels formed by 13 and 21 or 13 and 15, since the drag forces of the

grinding material flow directed radially inward on the grinding media are greater than the centrifugal forces of the grinding media directed radially outward on their curved paths. Correlations during operation are exactly opposite in the channels ("centrifugal channels") 21c and the rotor 21. The drag forces directed outwardly by the grinding material centrifuged radially outward act on the grinding media in conjunction with the also outwardly directed centrifugal forces, so that these are dragged radially outward. As a result, grinding media that always get into the radially inner area of the grinding space are again conveyed out. This prevents grinding media from accumulating on the radially inner separation device (not shown), thereby preventing an obstruction of the separation device, excessive wear of the grinding space, and an overheating of the grinding material in the radially inner area of the grinding space.

REFERENCE LIST

1	Engine bracket
2	Vertical element
3	Motor
4	Belt transmission
5	Pulley
6	Drive shaft bearing
7	Pivoting engine part carrier
8	Cladding
9	Grinding chamber
10	Hinge
11	Grinding material input opening
12	Grinding material output opening
13	First flat grinding chamber wall
14	Curved grinding chamber wall on grinding chamber periphery
15	Second flat grinding chamber wall
16	Screen jacket
17	Groove
18	Separation device, grading screen
19	Flange
20	Screws
21	Rotor, disk
21a	Radially inner hole
21b	Radially outer hole
21c	Channels
22	Pin on disk plane
23	Pin on disk edge
24	Pin on stator
25	Pin on stator
26	Screen cleaning pin
27	Connecting holes
28	Cladding
29	Cladding
30	Cladding